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Implementing Effective Natural Science Teaching Strategies in Education

Edviges Maria Sidalia de Oliveira

Instituto Católico para a Formação de Professores (ICFP) Baucau, Timor-Leste, 0009-0004-8317-3368
Corresponding author: Edviges Maria Sidalia de Oliveira (deviamanis@gmail.com)

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Abstract

The research aims to examine the effectiveness of learner-centred strategies (LCS) in the teaching of natural sciences in grade 5 classrooms in Timor-Leste, where the teaching-learning process is still characterized by teacher-centred learning (TCL), despite the curricular reforms. The qualitative descriptive design was employed, where the data were collected using semi-structured interviews, observation in classrooms, and analysis of documents by five science teachers in three schools in Baucau. The results indicate that inquiry-based learning theories and constructivist theories have been adopted by teachers who are increasingly adopting LCS strategies, including questioning, group work, problem solving, and guided demonstration. These plans have increased student engagement and participation, but the implementation process is limited due to insufficient resources, lack of ICT integration, and structural restrictions, including inappropriate classroom infrastructure and lack of access to science-related materials. Even though there was a positive attitude of teachers toward LCS, the lack of systematic assessment tools hampered the evidence of long-term learning outcomes. The study concludes that to ensure that Timor-Leste students develop critical, creative, and scientific skills in the 21st century, science education must be supported more effectively by institutions, teachers, and resources.

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Introduction

The success of teaching natural sciences is directly related to the approaches that teachers use to make their students interested in learning and help them gain insights. Strategies in teaching are not only methods of content delivery but also structures that determine how learners learn, become critical thinkers, and transfer ideas to real-life situations. Two main strategies prevail in science education: teacher-centred learning (TCL), in which the teacher is the main source of knowledge, and learner-centred strategies (LCS), in which students are involved in inquiry, problem solving, and reflection led by the teacher as a facilitator (Bhardwaj et al., 2025). TCL tends to promote passive knowledge consumption, whereas LCS has been found to improve student engagement, independence, and scientific competence.

Scientific competence is a combination of knowledge, skills, and attitudes that help people research natural phenomena, process information, and make informed decisions (Husamah, 2022). At the first level, such competence should be developed, in particular, since it helps to grow intellectually and utilize science in a practical way in daily life. The fifth grade is crucial in this process, as it marks the transition from the foundational knowledge stage to advanced reasoning and inquiry. Therefore, the discussion about the effectiveness of using strategies within the classroom of the fifth grade is necessary to enhance the results in science education.

Despite curriculum changes, Timor-Leste has maintained a teacher-centred approach to teaching. The national curriculum for 2014 explicitly encourages the use of learner-centred pedagogy, but most educators still apply traditional types of pedagogy that make students passive listeners (Cassity, Chainey, & Wong, 2022; Dos Santos, 2025). There are also various obstacles to the implementation of LCS: the lack of adequate teacher training, a lack of professional growth opportunities, and a lack of access to teaching resources and laboratories (Ximenes, 2024; Ximenes, 2025). In addition, there has been a lack of integration of information and communication technology (ICT) into the instruction of science, even though it has been noted that it can improve inquiry and conceptual knowledge (Ximenes, 2025). Due to this, students have little chance to be creative, think critically, and take an active part, which lowers the effectiveness of natural science teaching.

This background serves to indicate a research vulnerability. Although international research has shown that learner-centred methods are much more effective at improving student performance in science and other fields (Leal et al., 2022), the application of these methods in the context of Timor-Leste (and Grade 5 classrooms, in particular) has scarce empirical evidence. Structural and pedagogical issues in implementing the 2014 curriculum are identified in local research (Ximenes, 2025), but few studies have examined how teaching strategies are applied and how situational factors affect their implementation.

The provided research fills this gap by exploring the efficacy of natural science instruction in Grade 5 in the context of applying learner-centred strategies to basic education. It is informed by two research questions:

1. How well are primary school teachers in Timor-Leste applying the learning-centred strategies of the 2014 national curriculum for science instruction in Grade 5?
2. To what extent do these strategies promote independent, creative, and critical learning among fifth

graders?

This is an important study both academically and practically. In principle, it locates the practice of LCS in constructivist and inquiry-based learning models, which are part of the conversations around the world to adapt pedagogy to low-resource contexts. In practice, it presents evidence about the obstacles and possibilities of teaching science in Timor-Leste and has a recommendation about the training of teachers, curriculum, and the provision of resources. The study brings forward knowledge on effectiveness and implementation in fifth grade by offering perspectives on ways of making natural science education stronger and preparing students with the competencies that they need to learn in the 21st century.

Literature Review

Reputable educational theory, focusing on constructivist learning, inquiry-based learning, and learner-centred teaching, forms the foundation for successful science instruction. Constructivism, which is based on the works of Piaget, Vygotsky, and Bruner, also holds that learning occurs as an active process whereby learners actively construct their knowledge experiences instead of passively receiving information (Piaget, 1972; Vygotsky, 1978; Bruner, 1961). Teaching methods in the sciences emphasise exploration, experimentation, and building concepts through practical action and interpersonal interaction. According to the concept of the Zone of Proximal Development (ZPD), Vygotsky places significant emphasis on scaffolding, peer collaboration, and teacher assistance in helping learners advance beyond their present level of independent comprehension (Vygotsky, 1978). In the same way, discovery learning theory and the spiral curriculum proposed by Bruner focus on organised opportunities where students can revisit scientific concepts at a progressively more difficult level and achieve a more profound understanding as they proceed (Bruner, 1961). These theoretical frameworks form the basis of a significant number of recent science teaching methods, such as the assimilation of educational technology. Proponents like Papert (1980) extend the constructivist theory under constructionism and promote the learning environment where constructionist models and simulations are constructed and manipulated using digital means to explore scientific concepts. Collectively, the frameworks facilitate the transition to active and student-centred science teaching and lead to the incorporation of both empirical and technological advances in classroom-based practice.

Natural sciences taught at the primary school level have a wider scope than imparting facts. It also aims to further rational thinking, problem-solving, and intellectual growth through participation in scientific inquiry. Instead of simply delivering the content, modern science education focuses on approaches like observation, experimentation, questioning, and making conclusions to enhance student knowledge and encourage critical thinking (Suastiningsih, Wiarta, and Tirtayani, 2017). These are consistent with international standards for science education, which are becoming more inquiry-based and learner-centred (Fischer et al., 2005).

Empirical studies in the West have highlighted the significance of instructional approaches that encourage conceptual learning rather than simply memorising facts. A South African study by Set, Hadman, and Ashipala (2017) found that teachers tend to be very dependent on everyday examples, and they are unable to connect them to science concepts, which eventually hampers student comprehension. This issue, though, is not the one that concerns the region. Students in the UK, Canada, and Finland have noted that teaching science effectively relies on the professional knowledge of teachers, which involves how they integrate subject knowledge with pedagogical knowledge and realities in the classroom (Banks, 2011).

Researchers have identified that active, student-centred teaching methods in the classroom greatly impact learning. The studies reveal that the experiments, discussion-based, and problem-solving methods are more interactive and involve students in questioning and retention (Leal et al., 2022). The results align with more extensive educational research, in which learner-centred instruction is associated with an increase in academic performance in a wide range of subjects (including maths, science, and language) (Borko et al., 2007). In these situations, the teacher becomes not a source of information but a facilitator of learning as she assists pupils in building their own knowledge.

However, technological advances have presented new challenges to science education in recent years. Research has demonstrated that the use of educational technology (EdTech) tools, such as simulations, digital modelling, and blended learning environments, has measurable effects on student learning. A study on blended learning was conducted with Bayesian learning networks that showed that the students enrolled in a blended learning environment did better than their counterparts in terms of cognitive and conceptual knowledge (Wang, 2024). The model focused on real-time monitoring of the knowledge learning, which allowed the teacher to adjust the instructional approach to the needs of the students.

Besides blended learning, constructivist computer tools, like empirical modelling, have actually been suggested as potent supplements to conventional practices. Harfield (2007) associated these models with being more in line with the exploration character of scientific thought, and they may provide the basis for a new paradigm in science education. With the help of these tools, students can see, be entertained, and experiment with scientific concepts in a way that enhances meaningful learning.

In addition, gamification in scientific education is now recognised as a valuable tool to increase motivation and cognitive interest. A methodical examination of the research papers by Zeng and Shang (2018) revealed that educational games helped learners to become more motivated, think critically, and retain knowledge, but only when used suitably in tandem with curriculum objectives (Zeng and Shang, 2018). These technologies can be especially effective in working with younger students who might not be strong in abstract ideas in a classical environment.

To conclude, up-to-date studies are highly favourable for applying learner-centred pedagogical strategies using educational technology to enhance the results of science instruction. Western empirical research supports the usefulness of pedagogical knowledge, blended learning, and digital tools in the promotion of science literacy. Through the combination of these insights, the education of science will be able to meet the international standards and provide the learners with the competencies of the 21st century.

Methods

Research Design

In this study, the research design used a qualitative approach within a descriptive framework, which is well-suited for naturally examining and understanding classroom practices. The qualitative approach allows the researcher to collect deep and rich information about the way people perceive and give meaning to their experiences, especially in the dynamic context of teaching and learning (Castell et al., 2022). Descriptive qualitative research enables the articulation of data systematically, based on real-life experiences and observations, therefore providing a plausible explanation of the real-life phenomena (Stanley, 2023). Various methods of data collection, such as interviews, classroom observations, and document analysis, were used in this study to examine the teaching strategies of natural science teachers at the primary school level.

Sampling Strategy/Participants

The people involved in this study were a group of five teachers of natural science whose duties included teaching students of the fifth grade in three schools in the Baucau area, Timor-Leste. These schools were Escola Fundamental No.1-Baucau (EFN.1-Baucau), Saint Domingos Savio Catholic School (EKSDS) and CAFE Baucau School. A purposive sampling strategy was used to make the data relevant and rich. Qualitative studies that involve purposive sampling of cases when the aim of the research is to acquire in-depth understanding of the cases are suitable (Sugiyono, 2013).

To enhance transferability and transparency, the selection was conducted using some inclusion criteria: (1) the participant has to teach Grade 5 natural science; (2) the teacher has to complete at least three years of uninterrupted teaching experience in the subject; and (3) the participant must be engaged in the instructional planning or pedagogical development in their school. These requirements ensured that participants were not only knowledgeable but also thoughtful practitioners who could explain their teaching methods and issues. Furthermore, the sample included representatives from various institutional backgrounds—public, private, and NGO-backed—ensuring a wide range of perspectives and thereby enhancing the relevance of the study's results to other educational institutions.

Data Collection Techniques

Semi-structured interviews, non-participant classroom observations, and document analyses were used to gather data. The techniques facilitated the triangulation of results, thereby providing a more profound understanding of the studied teaching practice.

Interviews

All the teachers were involved in a single semi-structured interview, which lasted about 45–60 minutes. The interview plan contained a set of open-ended questions that were aimed at drawing detailed answers related to their teaching methods, their view on the effectiveness of teaching, classroom practice, and their expectations in the future. Some of the questions on the sample were: What are your current teaching strategies in your science lessons? What are the most difficult issues of implementing these strategies? What do you think of the reactions of students to your approaches? These fundamental questions promoted elaboration and clarification responses from the participants. The researcher conducted face-to-face interviews, recorded them with the participants' permission, and transcribed them verbatim to analyse the results (Brinkmann, 2022).

Observations

To validate and contextualise the data collected during interviews, classroom observations were made during the science instruction period. The process was guided by an observation protocol, and it incorporated teacher behaviour, student engagement, the use of instructional materials, classroom interactions, and the application of learner-centred strategies. The duration of each observation was one full class period (around 45 minutes), and field notes were recorded in detail to be able to record the dynamics and the nuances in their true time. One of the essential instruments of qualitative research is observation, which provides firsthand information about the real-time nature of interactions and instruction practices that may not be completely represented by interviews (Cohen, Manion, and Morrison, 2018).

Document Analysis

Teaching materials and lesson plans were also examined to gain another insight into how instructional choices were recorded and how they met national curriculum objectives. These texts were used to support the idea of triangulation between interviews and observations. Non-intrusive methods, such as document analysis, are valuable for adding data on the conceptualisation and formalisation of teaching decisions to the data collected during live observations and participants' stories (Merriam and Tisdell, 2016). A combination of these approaches helped deepen the meaning of results and led to a more comprehensive view of successful science teaching practice at the elementary school level.

Data Analysis

The analysis of data was done using thematic analysis, based on the six-phase model of structured analysis suggested by Byrne (2022). The steps involved in the analysis were as follows:(1) getting familiar with the data by reading transcripts and field notes repeatedly; (2) first code generation, which was performed manually and with the help of the qualitative analysis software; (3) the grouping of codes into the candidate themes; (4) revising and refining the themes to ensure their coherence and internal consistency; (5) defining and naming the themes to capture them; and (6) creating the final analytical narrative.

Several measures were taken to secure credibility. First, the use of investigator triangulation was adopted through involving a second researcher to code 20 per cent of the interview data independently of the researcher. Inter-coder reliability was also evaluated, and issues were sorted out through discussion and agreement. Second, crossvalidation of the results of interviews, observations, and document analysis comprised methodological triangulation (Nowell, Norris, White, and Moules, 2017). This combined methodology made the study's findings more credible, reliable, and confirmed.

Ethical Consideration

This study was conducted in accordance with ethical conduct to protect the rights, dignity, and professional integrity of the participants (Åkerfeldt & Boistrup, 2021). Before the data collection, the Instituto Catolico para a Formacao de Professores (ICFP) formally approved the ethical clearance, collaborated with the partner schools, and sent an information letter to them. All the participating teachers gave informed consent after being informed about the purpose, methods, and voluntary nature of their participation, including the privilege of dropping out at any given point. Pseudonyms that ensured confidentiality and anonymity through the removal of identifying information in transcripts and reports were used. Interviews, observations, document analysis and data gathering were carried out, whereby the workload of participants was considered and in line with the schedules of schools. Moreover, the project was intended to adhere to the cultural and institutional context of Timor-Leste, and all the information was safely stored and used exclusively for research. Such processes enhance the transparency, institutional responsibility and credibility of the study's results.

Results

Based on the information gained from the interview, the five interviewed teachers said that they had a positive attitude towards teaching science since the subject could be used to help students learn to know more about the natural world and obtain the ability to think critically. Teachers consistently expressed their application of learner-centred methods, aligning with the current curriculum's pedagogical orientation. Teachers mentioned questioning, guided demonstrations, group and individual tasks, classroom discussions, and problem-solving activities as strategies. Teachers thought that these techniques encouraged student participation and individual learning.

The implementation of LCS by all five teachers was confirmed using observational data. The example is that in classroom activities, the students were watched to be involved in small group work, in discussions, in structured observations and in answering open-ended questions. Students had submitted the results of group assignments in several instances and seemed to become involved in learning materials. The steps that a teacher took to deliver a lesson were largely the same as he or she went through: introduction, hands-on exploration, and reflective discussion. These practices validate the arguments of these teachers that they are trying to make student learning active.

However, the success of these strategies appears irregular across different classrooms. Although most of the students gave positive responses and showed an understanding level during the follow-up questioning, not all classrooms could engage. It was observed that a small group of students were passive or displayed behavioural problems such as a lack of motivation and an inability to follow instructions. These trends indicate that, even though the approach to learner-centred strategies has potential, it depends on various contexts to flourish successfully.

All five teachers cited structural restrictions that shortened the full implementation of LCS. A lack of science-specific teaching resources, insufficient access to textbooks and reference materials, poor or absent internet access and inadequate classroom furniture were the most common problems. As an example, the size of the classroom layout, consisting of broken chairs, or the creation of small discussion groups was limiting the possibilities of peer interaction. Another issue teachers mentioned was that low student motivation, particularly in smaller or mixed-ability classes, is a problem in keeping engagement at a high level. These limitations are supported by the field notes, where teachers describe improvised methods, like using local materials to demonstrate something.

Despite these challenges, the majority of observed lessons demonstrated student engagement, cooperation, and a certain level of content comprehension. The reaction of students to teacher questioning indicated that even in well-run contexts, LCS facilitated the process of knowledge building and greater engagement with science. However, it is premature to talk about better learning outcomes without assessments or recorded student performance data.In general, the evidence suggests that although the learner-centred strategies are being implemented, and they have the potential to enhance the learning of science, their effects are limited by classroom realities. The gap between teachers' dreams and their structural constraints shows the need for more professional development and resources. Moreover, in the future, the addition of direct measures of student learning would be advantageous to assess the efficacy of such pedagogical methodologies more strongly.

Discussion

The results of the present research have major consequences regarding the implementation of learner-centred strategies (LCS)-based teaching of natural science in Grade 5 resource-limited school settings. The continuous application of LCS by the teachers, including questioning, group work, observation, and problem solving, can be considered the development of agreement with constructivist and inquiry-based pedagogies as defined in the literature (Bruner, 1961; Vygotsky, 1978; Piaget, 1972). The observations in the classroom indicated that students interacted in groups, discussed, and often displayed conceptual knowledge in the effects of their answers. But exactly how these strategies achieved meaningful learning outcomes differed across classrooms, and the evidence indicates that implementation on its own cannot be effective.

The interaction of pedagogical strategies with contextual realities is a major concern in both the literature and this study. Although the theoretical background of LCS is quite reasonable, and the teachers involved demonstrated a reasonable level of awareness of the principles on which they are based, frequently supported by the previous training, their efficiency was often limited by systematic issues. These issues encompass restricted access to instructional resources, inadequate classroom facilities, ineffective internet connectivity, and inadequate technological application. These issues align with other works, such as those of Set, Hadman and Ashipala (2017), who noted similar implementation gaps in situations when teachers used examples that were not related to formal concepts in science.

Additionally, while teachers observed that their students were becoming more engaged and improving in critical thinking, these claims were largely based on personal perception rather than objective evidence. The results of the observations did confirm that more students were participating in certain classes; however, since there are no standardised tests or direct measures to measure the students' learning, it is hard to track the increase in understanding due to the use of LCS. This issue raises a methodological shortcoming that has also been identified in the empirical literature: teacher self-reports tend to overstate their impact unless learning outcomes are provided to support them (Borko et al., 2007). Therefore, LCS appears to promote active learning behaviours, but its relationship to achievement remains uncertain.

The other vital lesson of this study is the diversity of students' reactions to LCS. Although interactive strategies produced high performances among numerous students, some of them presented behavioural problems and lacked motivation. This data indicates that the assumption regarding the universal applicability of LCS is something that must be approached with some caution. According to Fischer et al. (2005) and Banks (2011), learner-centred instruction must be classroom-based, and teachers should not only understand pedagogical content knowledge but also have excellent classroom management skills and differentiation strategies.

Regardless of the limitations, some of the strategies applied by the teachers corresponded with the modern innovations in the teaching of science, including experimentation, discovery learning, and student-driven inquiry, which reflect the world's best practices (Leal et al., 2022). Nevertheless, the study also shows that digital tools and educational technologies, which have proven effective in promoting conceptual learning and cognitive growth in Western contexts (Wang, 2024; Harfield, 2007), are not used in the schools involved in the study. A digital divide is highlighted by the lack of effective ICT infrastructure and access to educational games or simulations, which makes it difficult to achieve 21st-century science competencies among students in these environments.

Moreover, it is crucial to consider other practical reasons for perceived improvements, such as teacher enthusiasm, small class sizes, or novelty effects. The personal commitment of teachers to this study was also commendable, and students may have been motivated by teacher enthusiasm to use the new strategies, regardless of their actual implementation. Furthermore, the LCS application in a small context can bring temporary participation results that cannot be maintained without continuous support and resource allocation.

Overall, even though the results confirm the theoretical and empirical importance of the learner-centred approach, they also demonstrate the complex nature of its implementation in under-resourced settings. The LCS relies not only on teacher understanding and commitment but also on the availability of instructional supports, a responsive school infrastructure, and institutional commitment to long-term pedagogical improvement. These results validate constructivist concepts, yet they also need researchers and policymakers to reframe learner-centred pedagogy as a situation-specific process, rather than a universal solution.

Conclusion

This study discussed the application of learner-centred strategies (LCS) to natural science teaching in the fifth grade in Timor-Leste. These results indicate that educators have started to use strategies that include questioning, group work, problem solving, and guided observation, which are in line with the constructivist and inquiry-based pedagogies. The methods encouraged student interaction, group work and increased student involvement in classes. Nevertheless, the paper has also pointed to the major structural and contextual obstacles that inhibited the effective and regular usage of LCS. These consisted of inadequate teaching materials, scanty access to science-specific materials and ICT, inadequate classroom facilities, and low student motivation in certain settings.

Although there was a positive attitude toward LCS and the realisation that it could positively influence critical thinking and independent learning among teachers, the difference in its effect was not evenly distributed among classrooms. Structural supports, teacher training, and resource provision cannot generalise and make learner-centred approaches efficient. Furthermore, the use of self-reports and classroom observations, without objective measures of student learning, renders questions about long-term outcomes unanswered.

Irrespective of these difficulties, the study makes an important contribution because it presents empirical evidence of the realities of implementing learner-centred science teaching in a low-resource setting. It indicates international literature, which confirms that LCS may result in better conceptual knowledge but emphasises that its success largely depends on local circumstances. In the case of Timor-Leste, the findings reiterate the importance of investing in professional teacher development, curriculum support, and classroom resources. Developing these fields will be crucial to making sure that the natural sciences education will provide the student with the skills that would help him or her think critically, solve problems, and survive in the 21st century.

Recommendation

According to the results of this research, it is possible to provide some recommendations to enhance the teaching of natural sciences in the fifth-grade classrooms in Timor-Leste:

1. Educator Learning.
   The education authority should implement continuous training programs to equip teachers with the necessary skills to effectively develop learner-centred strategies. These must involve inquiry-based teaching workshops, classroom management workshops, differentiation strategies workshops, and integration of ICT in science lessons.
2. Curriculum Representation and Coherence.
   Curriculum developers can provide teachers with practical lesson examples, scaffolding activities, and formative assessment tools to align daily instruction with constructivist principles.
3. Providing infrastructure and resources.
   Investments in classroom infrastructure, such as seating configurations that allow group work and access to electricity and the internet, should be made to ensure an environment that promotes LCS is achieved.
4. Introduction to Educational Technology.
   Examples of EdTech solutions that should be implemented to help students become more motivated and better understand concepts include simulations, gamification tools, and blended learning platforms. It will need an investment in ICT infrastructure and training teachers to engage in digital pedagogy.

5. Assessment and review of student learning.
   To quantify the actual effects of LCS, tools to measure the outcomes of students must be created. These may involve formative tests, project-based tests, and diagnostic measures that will monitor the progress and development of critical thinking, creativity, and scientific competence.
6. Policy and institutional commitment.
   Learner-centred pedagogy should be a priority for policymakers and school administrators in national education policies. Institutional support, through mentoring systems, supervision, and incentives for innovative teaching, will sustain pedagogical change over time.

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